CLAIMS

What is claimed is:

1. A mechanism for adjusting both the location of an object along a vertical axis and the rotational orientation of the object about a first and second horizontal axes, the first and second horizontal axes each being orthogonal to the vertical axis and to each other, the mechanism comprising:

means for retaining the object;

means for guiding motion of the retaining means, the guiding means permitting the retaining means to pivot about the first and second horizontal axes, the guiding means also permitting the retaining means to translate along the vertical axis, the guiding means preventing the retaining means from substantial translational movement in the plane defined by the first and second horizontal axes and substantial rotational movement about the vertical axis; and

means for translating at least three distinct areas of the retaining means substantially along the vertical axis, the three areas being positioned so that the retaining means may also be rotated about the first and second horizontal axes by the translating means, the object thus residing in a predetermined vertical location and rotational orientation about the horizontal axes.

2. The adjusting mechanism of claim 1, wherein the retaining means is a retaining plate designed to securely hold a printed circuit board.

3. The adjusting mechanism of claim 1, wherein the guiding means comprises at least three struts coupled at separate points around the perimeter of the retaining means, the struts extending outward and downward from the retaining means, the struts coupling the retaining means with a stable base.

4. The adjusting mechanism of claim 3, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

5. The adjusting mechanism of claim 1, wherein the guiding means comprises:

a first ball slidably mounted on a first vertical shaft mounted at the bottom end to a stable base, the first ball coupled with the retaining means to form a fixed-position ball joint wherein the first ball may rotate within a single position within the retaining means; and

a second ball slidably mounted on a second vertical shaft mounted at the bottom end to the stable base, the second ball coupled with the retaining means to form a sliding ball joint wherein the second ball may rotate and slide within a linear slot within the retaining means, the first ball lying within the line defined by the linear slot.

6. The adjusting mechanism of claim 5, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

7. The adjusting mechanism of claim 1, wherein the guiding means comprises:

a first pivot bearing slidably mounted on a first vertical shaft mounted at the bottom end to a stable base, the first pivot bearing coupled with the retaining means in a stationary manner that permits the retaining means to pivot about the two orthogonal horizontal axes; and

a second pivot bearing slidably mounted on a second vertical shaft mounted at the bottom end to the stable base, the second pivot bearing coupled with the retaining means by way of a flexure mounting to permit the retaining means to rotate about a

horizontal axis perpendicular to the axis defined by the first and second pivot bearings.

8. The adjusting mechanism of claim 7, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

9. The adjusting mechanism of claim 1, wherein the guiding means comprises:

at least two vertical shafts rigidly attached at the bottom end to a stable base;

a first coupling plate defining a hole for each vertical shaft, the shafts protruding through the holes so that the first coupling plate is held in a substantially horizontal fashion while being allowed to translate vertically;

a second coupling plate;

a first pivot joint coupling the first coupling plate with the second coupling plate, the first pivot joint permitting the second coupling plate to rotate only about the first horizontal axis; and

a second pivot joint coupling the second coupling plate with the retaining means, the second pivot joint permitting the retaining means to rotate only about an axis orthogonal to the first horizontal axis and parallel to the second coupling plate.

10. The adjusting mechanism of claim 9, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

11. The adjusting mechanism of claim 9, wherein the first and second coupling plates define centrally-located holes large enough so that the retaining means and the first and second coupling plates all lie within a single plane when the retaining means is oriented horizontally.

12. The adjusting mechanism of claim 1, wherein the translating means comprises at least three electric motors attached to a stable base, with each of the electric motors applying force to the retaining means along the vertical axis to the at least three distinct areas of the retaining means.

13. The adjusting mechanism of claim 12, wherein the electric motors are servo motors.

14. The adjusting mechanism of claim 12, wherein the electric motors are stepper motors.

15. The adjusting mechanism of claim 1, further comprising at least one spring compressed between a stable base and the guiding means to reduce the force required by the translating means to translate the retaining means upward along the vertical axis.

16. The adjusting mechanism of claim 1, further comprising at least one counterweight assembly applying force upward against the guiding means to reduce the force required by the translating means to translate the retaining means upward along the vertical axis.

17. A mechanism for adjusting both the location of an object along a vertical axis and the rotational orientation of the object about the vertical axis and a horizontal axis that is orthogonal to the vertical axis, the mechanism comprising:

means for retaining the object;

means for rotating the retaining means about the vertical axis;

means for guiding the movement of the rotating means, the guiding means permitting the rotating means to pivot about the horizontal axis, the guiding means also permitting the rotating means to translate along the vertical axis, the guiding

means preventing the rotating means from substantial translational movement in the horizontal plane and substantial rotational movement about either the vertical axis or an axis orthogonal to both the horizontal and vertical axes; and

means for translating at least two distinct areas of the rotating means along the vertical axis, the two areas residing on opposite sides of the horizontal axis, the translating means being capable of translating the rotating means along the vertical axis and pivoting the rotating means about the horizontal axis, the object thus residing in a predetermined vertical location and rotational orientation about the horizontal and vertical axes.

18. The adjusting mechanism of claim 17, wherein the retaining means is a retaining plate designed to securely hold a printed circuit board.

19. The adjusting mechanism of claim 17, wherein the guiding means comprises:

at least two vertical shafts rigidly attached at the bottom end to a stable base;

a coupling plate defining a hole for each vertical shaft, the shafts protruding through the holes so that the coupling plate is held in a substantially horizontal fashion while being allowed to translate vertically;

a pivot joint coupling the coupling plate with the rotating means, the pivot joint permitting the rotating means to pivot about the horizontal axis.

20. The adjusting mechanism of claim 19, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

21. The adjusting mechanism of claim 17, wherein the rotating means is a turntable driven by a rotational electric motor, the rotational electric motor being supported by a turntable base.

22. The adjusting mechanism of claim 17, wherein the translating means comprises at least two electric motors attached to the stable base, with each of the electric motors applying force to the rotating means along the vertical axis in at the least two distinct areas of the rotating means.

23. The adjusting mechanism of claim 22, wherein the electric motors are servo motors.

24. The adjusting mechanism of claim 22, wherein the electric motors are stepper motors.

25. The adjusting mechanism of claim 17, further comprising at least one spring compressed between a stable base and the guiding means to reduce the force required by the translating means to translate the rotating means upward along the vertical axis.

26. The adjusting mechanism of claim 17, further comprising at least one counterweight assembly applying force upward against the guiding means to reduce the force required by the translating means to translate the rotating means upward along the vertical axis.

27. A mechanism for adjusting both the location of a printed circuit board along a vertical axis and the rotational orientation of the printed circuit board about a first and second horizontal axes, the first and second horizontal axes each being orthogonal to the vertical axis and to each other, the mechanism comprising:

a retaining plate designed to securely hold the printed circuit board;

a mechanical guiding structure, the guiding structure permitting the retaining plate to pivot about the first and second horizontal axes, the guiding structure also

permitting the retaining plate to translate along the vertical axis, the guiding structure preventing the retaining plate from substantial translational movement in the plane defined by the first and second horizontal axes and substantial rotational movement about the vertical axis; and

at least three electric motors, with each applying force to the retaining plate along the vertical axis to at least three distinct areas, the three areas being positioned so that the retaining plate may be rotated about the first and second horizontal axes by the electric motors, the printed circuit board thus residing in a predetermined vertical location and rotational orientation about the horizontal axes.

28. The adjusting mechanism of claim 27, wherein the mechanical guiding structure comprises at least three struts coupled at separate points around the perimeter of the retaining plate, the struts extending outward and downward from the retaining plates, the struts coupling the retaining plate with a stable base.

29. The adjusting mechanism of claim 28, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

30. The adjusting mechanism of claim 27, wherein the mechanical guiding structure comprises:

a first ball slidably mounted on a first vertical shaft mounted at the bottom end to a stable base, the first ball coupled with the retaining plate to form a fixed-position ball joint wherein the first ball may rotate within a single position within the retaining plate; and

a second ball slidably mounted on a second vertical shaft mounted at the bottom end to the stable base, the second ball coupled with the retaining plate to form a sliding ball joint wherein the second ball may rotate and slide within a linear slot within the retaining plate, the first ball lying within the line defined by the linear slot.

31. The adjusting mechanism of claim 30, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

32. The adjusting mechanism of claim 27, wherein the mechanical guiding structure comprises:

a first pivot bearing slidably mounted on a first vertical shaft mounted at the bottom end to a stable base, the first pivot bearing coupled with the retaining plate in a stationary manner that permits the retaining plate to pivot about the two orthogonal horizontal axes; and

a second pivot bearing slidably mounted on a second vertical shaft mounted at the bottom end to the stable base, the second pivot bearing coupled with the retaining plate by way of a flexure mounting to permit the retaining plate to rotate about a horizontal axis perpendicular to the axis defined by the first and second pivot bearings.

33. The adjusting mechanism of claim 32, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

34. The adjusting mechanism of claim 27, wherein the mechanical guiding structure comprises:

at least two vertical shafts rigidly attached at the bottom end to a stable base;

a first coupling plate defining a hole for each vertical shaft, the shafts protruding through the holes so that the first coupling plate is held in a substantially horizontal fashion while being allowed to translate vertically;

a second coupling plate;

a first pivot joint coupling the first coupling plate with the second coupling plate, the first pivot joint permitting the second coupling plate to rotate only about the first horizontal axis; and

a second pivot joint coupling the second coupling plate with the retaining plate, the second pivot joint permitting the retaining plate to rotate only about an axis orthogonal to the first horizontal axis and parallel to the second coupling plate.

35. The adjusting mechanism of claim 34, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

36. The adjusting mechanism of claim 34, wherein the first and second coupling plates define centrally-located holes large enough so that the retaining plate and the first and second coupling plates all lie within a single plane when the retaining plate is oriented horizontally.

37. The adjusting mechanism of claim 27, wherein the electric motors are servo motors.

38. The adjusting mechanism of claim 27, wherein the electric motors are stepper motors.

39. The adjusting mechanism of claim 27, further comprising at least one spring compressed between a stable base and the mechanical guiding structure to reduce the force required by the electric motors to translate the retaining plate upward along the vertical axis.

40. The adjusting mechanism of claim 27, further comprising at least one counterweight assembly applying force upward against the mechanical guiding

structure to reduce the force required by the electric motors to translate the retaining plate upward along the vertical axis.

41. An x-ray laminography inspection system for inspecting a printed circuit board, comprising:

the adjustment mechanism of claim 27, the adjustment mechanism holding the printed circuit board;

a horizontal translation table attached to the adjustment mechanism;

an algorithmic controller that controls the movement of the adjustment mechanism and the horizontal translation table;

an x-ray source located near one side of the printed circuit board; and

an x-ray detector, the printed circuit board located between the x-ray source and the x-ray detector, the adjustment mechanism and the horizontal translation table positioning and orienting the printed circuit board so that an area of the printed circuit board being inspected lies substantially within the depth of focus of a focal plane located between and defined by the location of the x-ray source and the x-ray detector.

42. A mechanism for adjusting both the location of a printed circuit board along a vertical axis and the rotational orientation of the printed circuit board about the vertical axis and a horizontal axis that is orthogonal to the vertical axis, the mechanism comprising:

a retaining plate designed to securely hold the printed circuit board;

a turntable driven by a rotational electric motor, the rotational electric motor being supported by a turntable base;

a mechanical guiding structure that guides the movement of the turntable base, the guiding structure permitting the turntable base to pivot about the horizontal axis, the guiding structure also permitting the turntable base to translate along the vertical axis, the guiding structure preventing the turntable base from substantial translational

movement in the horizontal plane and substantial rotational movement about either the vertical axis or an axis orthogonal to both the horizontal and vertical axes; and

at least two electric motors, with each of the electric motors applying force to the turntable base along the vertical axis in at least two distinct areas of the turntable base, the two areas residing on opposite sides of the horizontal axis, the electric motors being capable of translating the turntable base along the vertical axis and pivoting the turntable base about the horizontal axis, the printed circuit board thus residing in a predetermined vertical location and rotational orientation about the horizontal and vertical axes.

43. The adjusting mechanism of claim 42, wherein the mechanical guiding structure comprises:

at least two vertical shafts rigidly attached at the bottom end to a stable base;

a coupling plate defining a hole for each vertical shaft, the shafts protruding through the holes so that the coupling plate is held in a substantially horizontal fashion while being allowed to translate vertically;

a pivot joint coupling the coupling plate with the turntable base, the pivot joint permitting the turntable base to pivot about the horizontal axis.

44. The adjusting mechanism of claim 43, wherein the stable base is a horizontal translation table capable of translating the adjusting mechanism horizontally.

45. The adjusting mechanism of claim 42, wherein the electric motors are servo motors.

46. The adjusting mechanism of claim 42, wherein the electric motors are stepper motors.

47. The adjusting mechanism of claim 42, further comprising at least one spring compressed between a stable base and the mechanical guiding structure to reduce the force required by the electric motors to translate the turntable base upward along the vertical axis.

48. The adjusting mechanism of claim 42, further comprising at least one counterweight assembly applying force upward against the mechanical guiding structure to reduce the force required by the electric motors to translate the turntable base upward along the vertical axis.

49. An x-ray laminography inspection system for inspecting a printed circuit board, comprising:

the adjustment mechanism of claim 42, the adjustment mechanism holding the printed circuit board;

a horizontal translation table attached to the adjustment mechanism;

an algorithmic controller that controls the movement of the adjustment mechanism and the horizontal translation table;

an x-ray source located near one side of the printed circuit board; and

an x-ray detector, the printed circuit board located between the x-ray source and the x-ray detector, the adjustment mechanism and the horizontal translation table positioning and orienting the printed circuit board so that an area of the printed circuit board being inspected lies substantially within the depth of focus of a focal plane located between and defined by the location of the x-ray source and the x-ray detector.

50. A method for adjusting both the location of an object along a vertical axis and the rotational orientation of the object about a first and second horizontal axes, the first and second horizontal axes each being orthogonal to the vertical axis and to each other, the method comprising the steps of:

guiding the motion of the object by permitting the object to pivot about the first and second horizontal axes and to translate along the vertical axis, while preventing the object from substantial horizontal translational movement and substantial rotational movement about the vertical axis; and

translating at least three distinct areas of the object substantially along the vertical axis, the three areas being positioned so that the object may also be rotated about the first and second horizontal axes, so that the object resides in a predetermined vertical location and rotational orientation about the horizontal axes.

51. A method for adjusting both the location of an object along a vertical axis and the rotational orientation of the object about the vertical axis and a horizontal axis that is orthogonal to the vertical axis, the method comprising the steps of:

guiding the motion of the object by permitting the object to pivot about the horizontal axis, to rotate about the vertical axis, and to translate along the vertical axis, while preventing the object from substantial translational movement in the horizontal plane and substantial rotational movement about an axis orthogonal to both the horizontal and vertical axes;

rotating the object about the vertical axis; and

translating at least two distinct areas of the object along the vertical axis, the two areas residing on opposite sides of the horizontal axis, so that the rotating and translating steps cause the object to reside in a predetermined vertical location and rotational orientation about the vertical and horizontal axes.